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greenius - A NEW SIMULATION ENVIRONMENT FOR TECHNICAL AND ECONOMICAL ANALYSIS OF RENEWABLE INDEPENDENT POWER PROJECTS

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ABSTRACT

The use of modern simulation tools when planing renewable independent power projects minimizes the risks of these projects. Simulation tools can also help to find the best project site for a special technology or the best technology for a special site. However, a user-friendly powerful simulation tool that provides detailed technical as well as economical analysis of multiple technology types such as photovoltaics, wind energy and solar thermal power plants did not exist until now.

The new simulation environment **greenius** offers all these possibilities. The main emphasis when developing this software was on the user-friendly interface and the calculation performance. Some simulation results demonstrate the capabilities of the **greenius** software.

INTRODUCTION

The technical and economical analysis of renewable independent power projects is essential to minimize the technical and financial risks while planning renewable power projects. Most modern computer simulation tools only offer the possibility of technical analysis for some renewable technology types. A comfortable and professional simulation tool for solar thermal power plants does not exist. For the simulation of small grid connected photovoltaic systems several simulation tools are available, however most of them are optimized for the European photovoltaic market. For the analysis of wind power plants there are powerful but expensive tools, that can be only used by specialists. Nevertheless none of the existing tools combine detailed technical with financial analysis. To gap this bridge the new computer simulation environment **greenius** has been developed.

MODELLING A RENEWABLE POWER PROJECT

The most important emphasis during the development of **greenius** was put on the user-friendly structure and interface. All parameters are pre-defined with realistic values, so that the fist simulation runs can be done in seconds without harassing with incomprehensible manuals. Project cases are organized in a logical tree structure displaying always a short summary of the key figures. Behind the summary there are additional interfaces with detailed information, thus supporting the user to define the project top-down. An overview of the **greenius** tree structure is shown in Fig. 1. A database for all components is available and can be modified and enlarged by the user. Furthermore, it is possible to open several project cases at the same time as it is standard at common Windows applications.

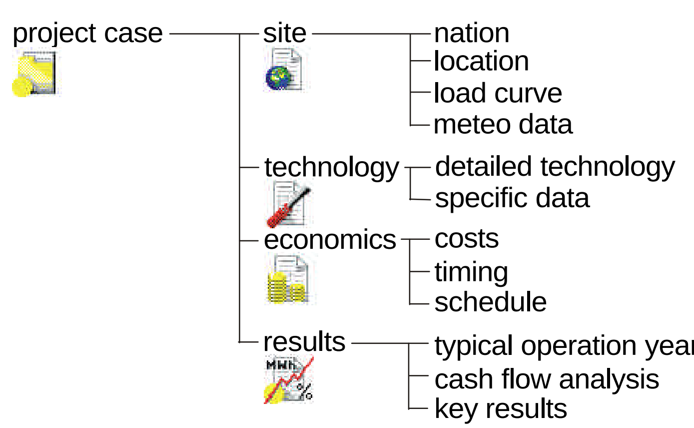

Fig. 1: The **greenius** tree structure.

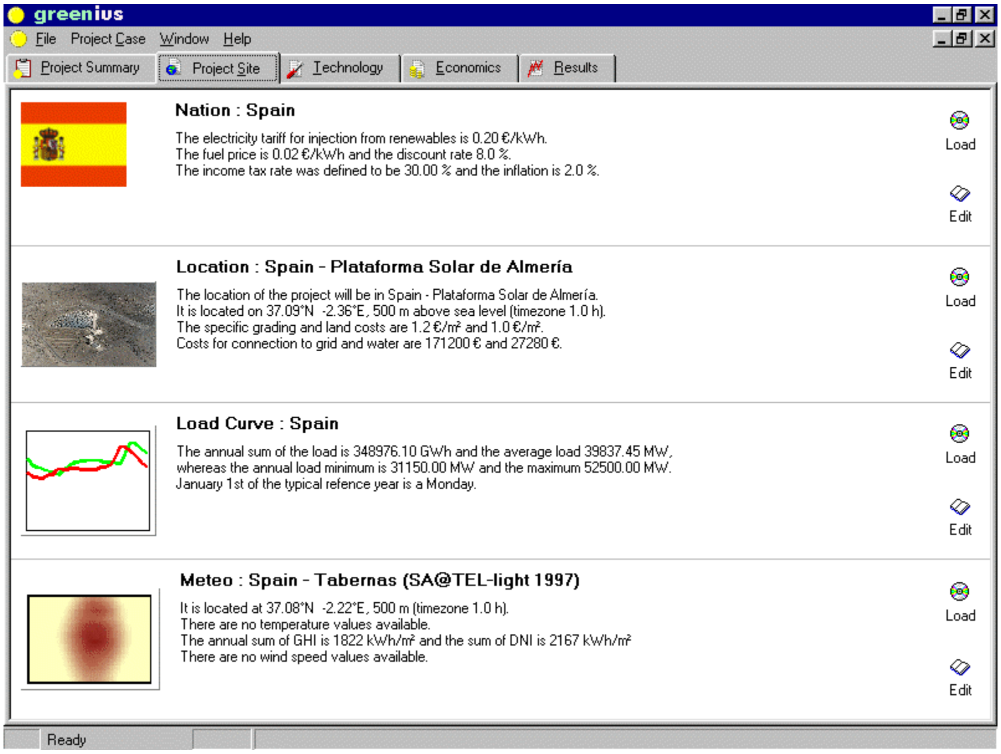

Fig. 2: Screenshot of the **greenius** project site summary.

PROJECT SITE DEFINITION

The project site form contains all parameters used to define the place of the potential project location. This includes geographical parameters as well as economical parameters used for the economical analysis such as land costs, costs for water supply, electricity tariffs or discount rates. These data are then subdivided in four major groups:

- nation specific data
- location specific data
- electrical load curve data
- meteorological data.

A screenshot of the project site interface is shown in Fig. 2. The *Nation* interfaces summarizes data on the existing electricity tariffs of the specific country as well as some macroeconomic data, e.g. inflation rate, discount rate, etc.. The Location group contains information on the geographical location, on properties of the ground and some infrastructure data mainly on electricity grid and water connection. The *Meteo* interface provides the user an input filters for the meteorological data to import TMY2 data files or even ASCII-files if hourly values are available. Comfortable graphical tools can visualize the parameters and they can be exported to other Windows applications.

A load curve designer can be used to create easily a load curve if no ASCII-data are available. Load curves can be used to define a guaranteed load to be generated by the renewable system. If no load curve is defined, the calculations are done in the solar only mode. That means the renewable power system generated as much as possible by renewable sources.

TECHNOLOGY DEFINITION

The aim of the **greenius** simulation environment is to implement the most important renewable technologies. This allows the planner to compare possible renewable supply solutions at the same site. Today the following systems can be analyzed with **greenius**:

- grid connected photovoltaic systems (see Fig. 3)
- wind power plants
- solar thermal trough power plants
- Dish/Stirling systems

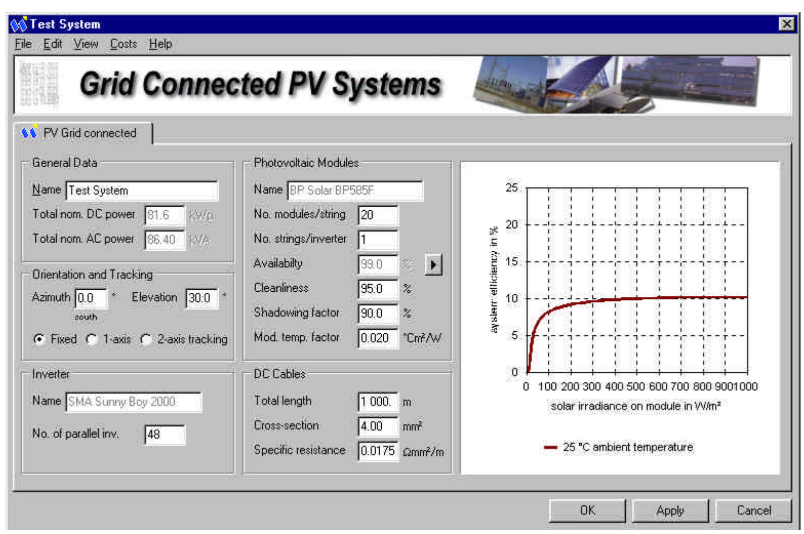

Fig. 3: Screenshot of the **greenius** photovoltaic module definition form.

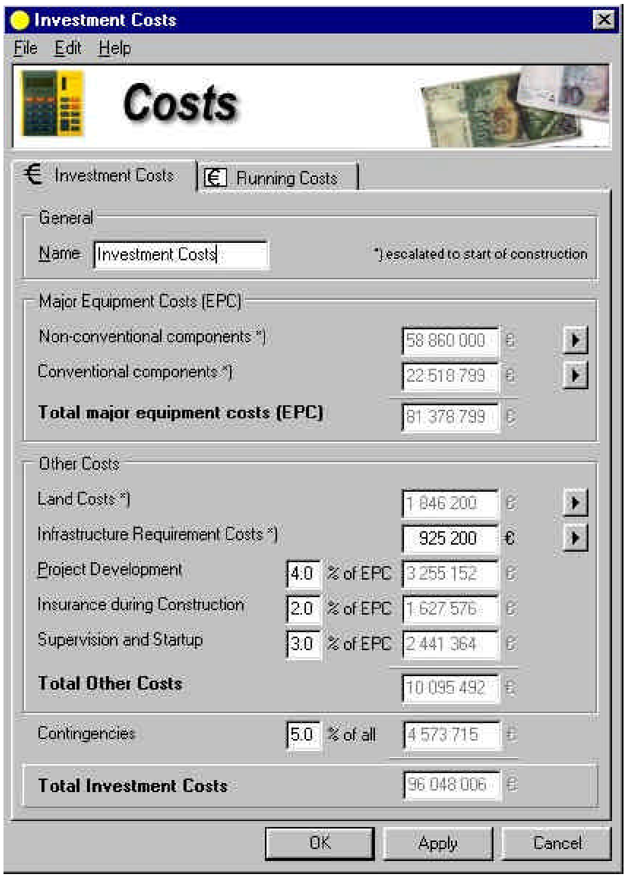

Fig. 4: Screenshot of the **greenius** costs definition form.

Other technologies such as solar thermal tower systems, hydro power plants, biomass power plants and fuel cells shall be implemented in the next steps.

It is possible to assemble the technical system with components from an extensive database for photovoltaic modules, photovoltaic inverters, wind energy converters or solar thermal collectors. All parameters of the components can be customized, but are highlighted red if they are outside of a realistic range. This avoids wrong parameter definitions and, finally, unrealistic results. From the parameters online characteristics are calculated. These graphics allows to analyze parameters and to point out wrong values.

ECONOMY DEFINITION

The economical parameters are used for estimating economical key parameters as well as extensive cash flow calculations over the entire lifetime of the project. Detailed system costs are calculated by pre-defined or customized specific investment costs parameters and additional project development costs, land costs and start-up costs (Fig. 4). A detailed project schedule - with detailed timing information on the construction and operation phase - can be drawn up within the *Timing* interface. Comprehensive financing schemes can be adapted on the *Financing* sheet. The influence of grant elements and debt ratios on the financial performance of the specific project can be analyzed. Debt financing can be subdivided in multiple tranches each with individual terms of credits, i.e. interest rate, debt terms, grace, period, etc.

RUNNING SIMULATIONS

The user can start with only two mouse clicks the simulation, just by selecting the corresponding technology and a meteo data file. All further parameters are pre-defined with realistic values, but can also customized.

All simulations are done for a typical operation year in hourly time steps. Precise but fast algorithms are implemented. Fig. 5 shows the structure of algorithms for the simulation of a parabolic trough system. The aim to keep the simulation time noticeable below half a minute was achieved for all technologies. Although for the heating-up process for parabolic trough power plants one minute iteration steps are necessary, a Pentium-II 400 MHz computer runs a simulation in less then 30 seconds.

As results of the simulations **greenius** records results of a various detailed parameters. The results can be visualized in a data table or in graphs (Fig. 6) and can be saved or exported to other Windows™ applications, e.g. MS Excel™. Some of the computed key results are:

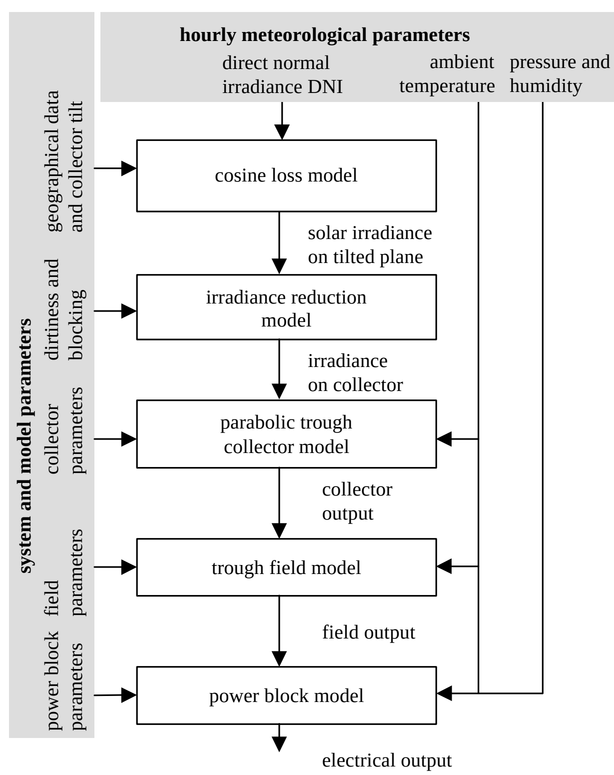

Fig. 5: Structure of parabolic trough simulation.

- Annual electricity generation
- System efficiency
- Efficiencies of subsystems
- Annual performance ratio

Besides the technical simulations **greenius** delivers extensive cash-flow sheets of the analyzed project showing the cash flow of the capital injection, the revenues and O&M cost schedule as well as the detailed debt service. By means of the cash flow the power economic key figures can be computed, such as:

- Levelized Electricity Costs (LEC)
- Internal Rate of Return (IRR)
- Net Present Value (NPV)
- Incremental Costs
- CO_2 avoidance costs

For a final assessment of the simulation results, **greenius** provides the user a summary of the key results on one sheet. By means of theses results the user can:

- find the least-cost technology for a specific project site
- optimize the configuration for a specific technology
- find the least-cost project site for a specific renewable technology
- find the optimum financing scheme

TECHNOLOGY COMPARISION WITH GREENIUS

Figure 6 should demonstrate the capability of the **greenius** simulation environment.

Fig. 7 shows the levelized electricity costs for photovoltaic and solar thermal trough power plants obtained from simulation runs with **greenius**. More than 60 sites in Europe and Northern Africa have been simulated. For the photovoltaic systems two different runs with present costs and 50 % reduced costs are done. The costs for solar thermal power plants were kept constant. Even in the case with 50 % cost reduction for photovoltaic systems the levelized electricity costs for solar thermal power plants are lower south of the 47 degree of latitude.

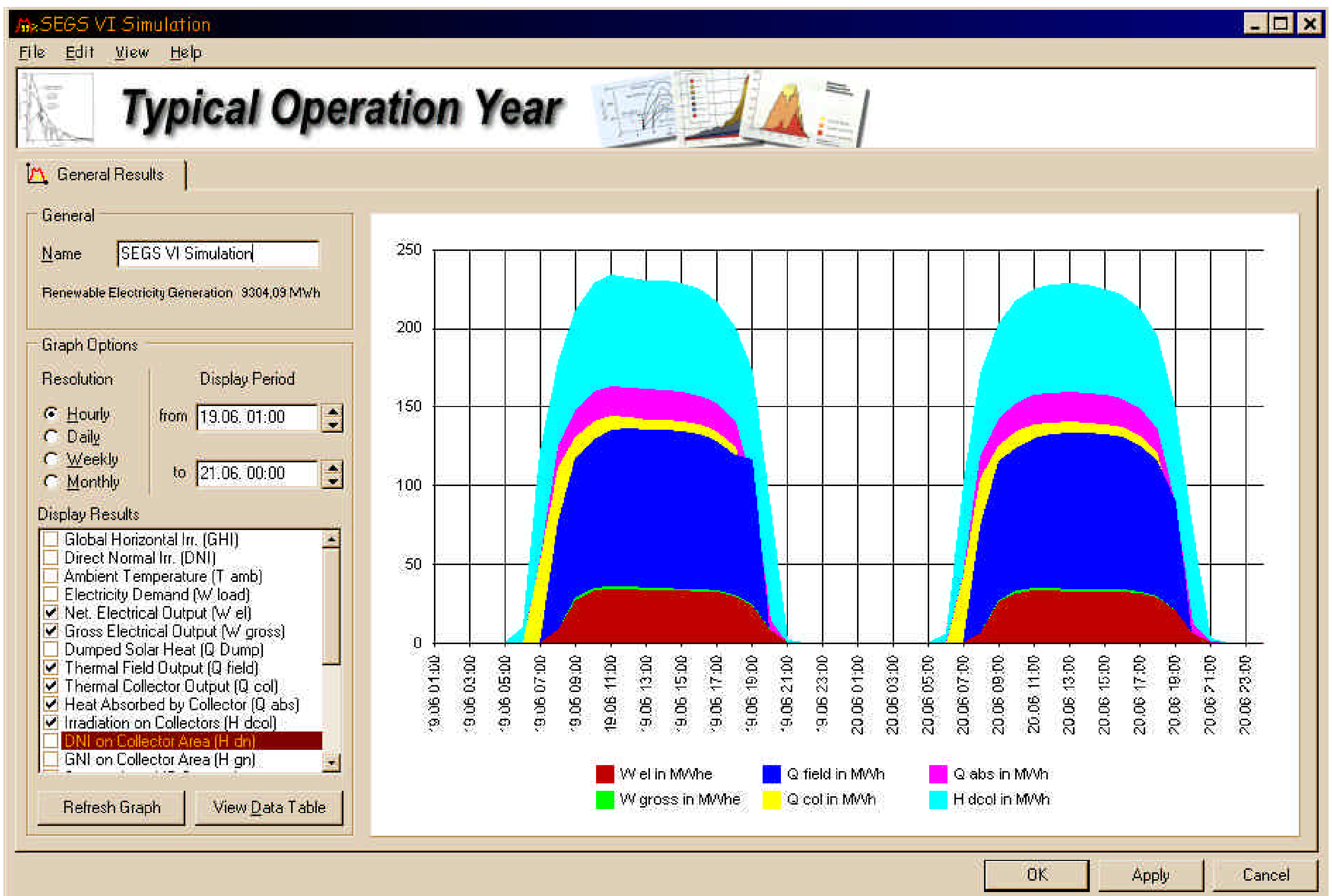

Fig. 6: **greenius** hourly simulation of the parabolic trough power plant SEGS VI.

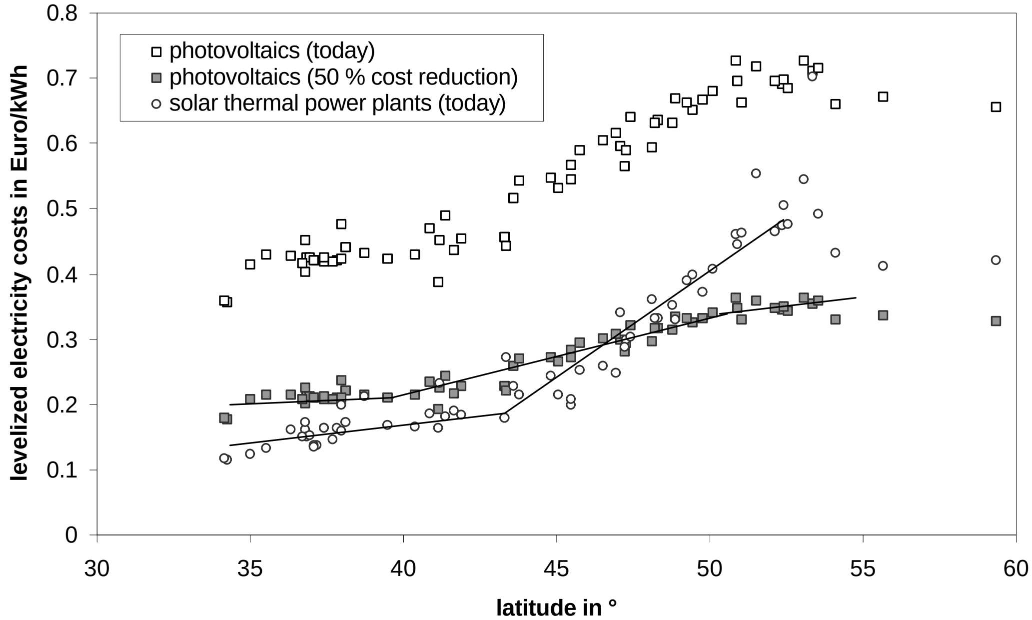

Fig. 7. Simulation results for the LEC key value for photovoltaic systems and solar thermal power plants in Europe and Northern Africa

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